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ABSTRACT

Two studies examined the relationship between cognitive style as determined by conjugate lateral eye-movements and the ability to recognize correct inferences and specific items from textual and pictorial displays. Subjects were given related sets of sentences and pictures followed by separate inference and recognition memory tests. Results of Experiment 1 showed that left movers or right-hemisphere dominant subjects (LEM/RH's) recognized more verbal inferences than pictorial inferences, whereas right movers or left-hemisphere dominant subjects (REM/LH's) recognized both types of inferences equally well. Further, the overall recognition memory score of LEM/RH subjects was greater than REM/LH subjects. Analysis of the inference data of Experiment 2 found that LEM/RL's subjects had higher mean inference scores than REM/LH's subjects. The results of both experiments were contrary to conjugate lateral eye-movement theory. Suggestions for a more integrative bimodal theory were discussed. (Author)

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Relation of Conjugate Lateral Eye
Movements to Inferential Reasoning
and Semantic Comprehension

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Abstract

Two studies examined the relationship between cognitive style as determined by conjugate lateral eye-movements and the ability to recognize correct inferences and specific items from textual and pictorial displays. Subjects were given related sets of sentences and pictures followed by separate inference and recognition memory tests. Results of Experiment 1 showed that left movers or right-hemisphere dominant subjects (LEM/RH's) recognized more verbal inferences than pictorial inferences, whereas right movers or left-hemisphere dominant subjects (REM/LH's) recognized both types of inferences equally well. Further, the overall recognition memory score of LEM/RH subjects was greater than REM/LH subjects. Analysis of the inference data of Experiment 2 found that LEM/RH's subjects had higher mean inference scores than REM/LH's subjects. The results of both experiments were contrary to conjugate lateral eye movement theory. Suggestions for a more integrative bimodal theory were discussed.

Relation of Conjugate Lateral Eye
Movements to Inferential Reasoning
and Semantic Comprehension

A growing body of research indicates that individual differences in cognitive style may be related to differential use of the two cerebral hemispheres (e.g., Bakan, 1971; Doktor & Bloom, 1977; Duke, 1968; Dunn, in press; Gur, 1975; Gur & Gur, 1977, Ornstein & Galin, 1976). A particularly promising and simple approach for inferring cortical activity as it relates to processing style is the preferred direction of subjects' conjugate lateral eye-movements (e.g., Bakan, 1971; Gur, 1975). Although some controversy exists regarding the consistency of lateral shifts during reflective thinking, Gur (1975) has produced strong evidence that anxiety, caused by face-to-face situations, produces lateral eye-movements in the subjects' preferred direction. This preferred direction occurs regardless of the type of information processing (verbal or visuospatial) called for by the specific question. Right eye-movements supposedly indicate left hemispheric activity associated with sequential-analytic processing; left eye-movement indicates holistic right-hemispheric activity. Thus, consistent right eye-movers are seen as predominantly left hemispheric, analytic processors and consistent left eye-movers are seen as right hemispheric, holistic processors.

No one to our knowledge has investigated how left eye-movers or right hemispheric processors (LEM/RH) differ from right eye-movers or left hemispheric processors (REM/LH) on semantic inference tasks. This is somewhat surprising given the recent interest in the relation between cognitive style and personality difference and performance on prose related tasks (e.g., Dunn, in press; Spiro & Tirre, 1979). Thus, the primary aim of the series of studies reported today was to determine if conjugate lateral eye-movements were reliably related to differences in inferential performance.

The acquisition and testing tasks used in all our experiments were similar to those used by Moeser (1976) who modified the Bransford and Franks (1971) inference task. During acquisition subjects were given different triad items, half consisting of sentences and the other half consisting of pictures with each triad depicting three related ideas. For example:

The snake was in the hat.

The hat was in the basket.

The basket was in the garden.

During testing they were first asked to choose between true and false inferences, i.e., The snake was in the garden (T), or The snake was in the wagon (F). Inference testing was immediately followed by a memory test where subjects were asked to report if he or she had ever seen a given sentence or picture, e.g., The snake was on the book (F) or The snake was in the hat (T).

If the Gurs' (Gur & Gur, 1977) are correct concerning the relationship between direction of lateral eye movements and cognitive style, then it could be predicted that consistent REM/LH (analyticals) should obtain greater inference scores than consistent LEM/RH (holistics) because of the logical and sequential nature of Bransford and Franks (1971) type of inferential task used in this study. However, because language is more analytical than pictorial information, the right movers (left hemisphere predominant) should produce higher verbal inference scores than pictorial inference scores, with just the opposite pattern being produced by the left movers (right-hemisphere dominant). Experiment 1 was designed to test this notion.

Experiment 1

Method

Two sets of acquisition materials were made with each set consisting of four complex ideas. The left side of Table 1 of your handout shows the sets used in Experiment 1. Each complex idea consisted of three Place Table 1 about Here related propositions that were always presented sequentially in the logical order indicated: 1) The snake was in the hat; 2) The hat was in the basket; and 3) The basket was in the garden. Two versions of each set of four complex ideas were made. In one of the versions each proposition was printed in sentence form. In the other version a line drawing represented the proposition and pictured a snake in the hat.

Each of the propositions making up the various complex ideas were photographed in negative contrast using 35 mm film. This allowed each proposition to be shown individually during acquisition.

Subjects and Procedure

Forty-eight upper-division university students, 24 males and 24 females, were individually administered the Laterality Assessment Inventory for handedness (Sherman & Kulhavy, 1976) and the Conjugate Lateral Eye-Movement Inventory (LEM), (Gur & Gur, Note 1). The Sherman & Kulhavy (1976) handedness inventory consists of a 30-item questionnaire. Subjects were required to indicate for each item on the questionnaire which hand they use for a given task (e.g., in which hand do you turn a door knob?) and the degree to which they use that hand.

The Conjugate Lateral Eye-Movement Inventory consists of 20 randomly-ordered items designed to elicit differential hemispheric activation. Ten of the items deal with definitions of words and explanations of proverbs (e.g., name synonyms for the word good; explain "Strike while the iron is hot"). The remaining ten questions require the subject to make visualizations (e.g., visualize the map of Europe. What are the countries that border Switzerland?). Theoretically then, half of the inventory (definitions and proverbs) engages the left (analytic) hemisphere, while the remaining half engages the right (holistic) hemisphere.

Direction of lateral eye movement was recorded by one of the experimenters under a face-to-face interaction with the subject.

Immediately after the question was given, the direction of the subjects' first eye movement was recorded. If the subject gazed to their right (the experimenters' left) it was recorded as a right eye movement, etc.

After the administration of the handedness and eye movement inventories, subjects were presented with the verbal and pictorial acquisition sets containing four complex ideas each. Testing was conducted on an individual basis and subjects were instructed to learn each sequence or triad of slides (complex idea) as well as possible because they would later be asked questions concerning them. Following a suggestion by Thorndyke (1976) the word "learn" was used rather than the word "memorize" in order to induce subjects to pay attention to the meaning as well as the "syntax" of the pictures and sentences. Each slide or proposition was shown for five seconds allowing fifteen seconds per complex idea. Each complex idea was followed by ten seconds of blank projection.

Because pilot work had shown Sets A and B to be equivalent in difficulty, all subjects received Set A information first followed by Set B information. However, one-half of the subjects received Set A in sentence form first, followed by Set B in pictorial form. The remaining half received Set A pictorial first and Set B sentences second. The order of ideas within each set was also counterbalanced.

At the end of the acquisition phase, subjects were presented sequentially with 64 test items. Subjects were told that they would be shown a series of slides, each containing a sentence or picture, and that each of the slides was related closely to the acquisition sets they had just seen. They were instructed that their task was to determine if the information presented on each of these slides was correct or incorrect based on the information learned from the three slide sequences. They were asked to respond verbally to each slide by stating true if it was judged correct and false if it was not. The left side of Table 2 of your handout shows an example of the testing sequence.

Place Table 2 About Here

Note that the false inference and false memory statements contain incorrect combinations of the acquisitional propositions. Thus, any difference in responses to true and false propositions could not be attributed to novel words, subjects or objects. Please also note that both the inference and memory questions were shown in pairs and that one of the members was true and the other false. Slides were shown for five seconds each.

Following the procedure used by Moeser (1976), inference testing for both acquisition sets always occurred before the memory tests of those sets. Thus, for example, if a given subject had first received

Set A in sentence form during acquisition, the order of his/her testing sequence occurred in the following order: 8 sentence inference questions; 8 pictorial inference questions; 24 sentence memory questions; and 24 pictorial memory questions, respectively.

The design for the experiment was a three-way mixed design. The between independent variables were sex of subject, type of lateral eye mover (right or left). The within or repeated independent variable changed with the dependent variable being analyzed, i.e., pictorial vs. sentence memory or pictorial vs. sentence inference scores. Gender was treated as an independent variable because recent research has indicated that females' cognitive functioning may not be as lateralized as males' (Davidson & Schwartz, 1977; Gur & Gur, 1977).

Results and discussion. The handedness data showed only three subjects were not primarily right handed. Thus, these data are not discussed further.

Lateral eye movement scores were dichotomized so that subjects who had greater than 50% right eye movements were considered right movers (analyticals with left-hemisphere dominance), and those with greater than 50% left eye movements were classified as left movers (holistics with right-hemisphere dominance). A three-way mixed ANOVA performed on the inferential data found both the type of stimulus (pictures or sentences) main effect and the two-way type of mover (left vs. right) by type of stimulus interaction to reach significance, $F(1,44) = 8.19, p < .006$; $F(1,44) = 5.88, p < .02$, respectively.

The main effect showed subjects' mean verbal inference score (6.08) was greater than their mean pictorial score (5.63). The pattern of the two-way interaction suggested that LEM/RH (holistics) made more verbal inferences (6.67) than pictorial inferences (5.25), whereas right movers (analytics) made about the same pictorial (5.89) as verbal (5.75) inferences.

When the memory data were analyzed using a similar three-way ANOVA, only the main effect of type of mover was marginally significant, $F(1.44) = 3.97$, $P < .052$. LEM/RH's mean recognition of the original acquisition items was slightly higher (22.9) than REM/LH's (21.1). These results, particularly the inference data, are somewhat at variance with the direction predicted by Gurs' lateral eye movement theory, which argues that right movers use more left-hemispheric processing (logical, verbal analytical, sequential, etc.) than left movers, the latter of which supposedly use more right-hemispheric processing.

Assuming that making inferences is an analytical task, the REM/LH analytics should have made higher scores than LEM/RH holistics. They did not. Further, they should have performed better on verbal than on pictorial inferences but their performance on both was about the same. Even though LEM/RH holistics should have done worse than REM/LH analytics overall, they should have higher pictorial than sentence inference scores because pictorial presentation is more appropriate for their particular cognitive style. As we have seen,

not only was their overall performance about the same, their pattern of pictorial and sentence inferences was just the reverse of what would be expected from the Gurs' theory.

Because of the data were in the opposite direction of the predictions derived from the Gurs' theory (Gur & Gur, 1977), a second experiment was conducted. Interestingly, the pilot to that experiment produced ceiling effects on both inference and memory data. The pilot differed from Experiment 1 in two major ways: 1) The testing instructions were made less ambiguous and more ecologically valid by telling subjects that the first two tests were inference tests and the second two were memory tests. That is, they were instructed to respond true or false if the information was a correct or incorrect conclusion or inference based on a given acquisition triad or complex idea. They were also told that during memory testing, they were to state true or yes if they had seen that slide during acquisition and false or no if they had not. (Remember that in Experiment 1 subjects only were asked to respond "true" if the test slide was correct given the acquisition triads, and false if it was incorrect for both the inference and memory tests). 2) As can be seen on the right half of Table 1 of your handout, the order of the second and fourth triads of both Sets A and B were altered so that the sentences or pictures contained in these triads were not in the same logical sequence of the first and third triads. This produced another independent

variable called order (logical/non-logical) (e.g., a non-logical order was 1. The wagon was in the tent; 2. The frog caught the lizard; and 3. The lizard was on the wagon.

Based on the results of the pilot experiment, the testing procedure for Experiment 2 was modified to make it more difficult, thereby helping to reduce the pronounced ceiling effect.

Experiment 2

Method

Materials. The changes in the testing procedure can be seen on the right half of Table 2 of your handout. Note that for both inference and memory testing the slides were randomized and were not presented in related pairs to the subjects as they had during Experiment 1 and the pilot experiment. It is important to point out here that this procedure significantly reduced the ceiling effect for all conditions.

Subjects and procedure. All procedures and materials were exactly the same as the pilot experiment with the one exception that subjects conjugate lateral eye movements were monitored by a hidden video tape camera. Twelve male and twelve female volunteer freshmen and sophomore students participated.

Results

The inference data were analyzed using a four-way mixed analysis of variance. The between I.V.'s were: Sex (male/female) and type of eye mover (left/right). The within I.V.'s were type of inference score (sentence/pictorial) and proposition order within triads (logical/non-logical). The only main effect that was statistically significant was type of eye mover ($F(1,20) = 4.82, P < .04$), with LEM/RH holistics having greater mean inference scores (2.73) than REM/LH analytics (2.11). The only interaction to reach significance, unfortunately, was the four-way interaction, ($F(1,20) = 4.61, P < .05$). Various plots and prayers concerning the interaction suggested to us that it was caused primarily by differences among female LEM's and REM's when given sentences presented in logical order. In all other presentation cases (i.e., when subjects were given non-logically ordered sentences and pictures and logically ordered pictures), LEM/RH holistics of both sexes produced higher mean inference scores than their REM/LH counterparts. Even male LEM/RH holistics had higher inference scores than male REM/LH analytics when given sentences in logical order. In contrast, female LEM/RH holistics had a lower mean logical sentence inference score than female REM/LH analytics. Please note that both these results, particularly the main effect of eye mover are again opposite to the predictions of the Gurs' (1977) theory.

Analysis of the memory test data using a four-way, mixed analysis of variance similar to that used on the inference data yielded significant main effects for type of memory question (sentence vs. pictures) and order proposition order within triads (logical vs. non-logical): $F(1,20) = 6.96, P < .02$; $F(1,20) = 4.60, P < .05$, respectively. The mean memory recognition of picture stimuli was greater than sentence stimuli (10.30 vs. 9.32, respectively) and logically ordered stimuli had a higher mean memory recognition score (10.00) than non-logically ordered stimuli (9.60).

The only interaction to reach significance was the sex by proposition order interaction ($F(1,20) = 7.54, P < .02$) which indicated that males' mean recognition score for logical information (10.34) was greater than for random information (9.34) whereas females' showed no change. If anything, females' mean recognition score for logical information was slightly lower (9.73) than their mean for random information (9.85).

General Discussion

Assuming that making or recognizing inferences is an analytical task requiring extensive left-hemispheric processing, then the results of both experiments reported today appear to be counter to the simple "hemisphericity" theory held by the Gurs (Gur & Gur, 1977) and others (e.g., Ornstein, 1977). Analysis of the data of Experiment 1 revealed that contrary to the Gurs' theory, LEM/RH holistics performed better.

on sentence or verbal inferences than they did pictorial inferences. In contrast, REM/LH analytics did no better on verbal than on pictorial inferences. Further, although just marginally significant, the memory data of Experiment 1 showed that the LEM/RH holistics recognized slightly more of the acquisition propositions than did the REM/LH analytics.

Although not completely replicating Experiment 1, probably because of differences in instructions and testing procedures, the inference data of Experiment 2 were also contrary to simple hemisphericity theory. The inference data showed that LEM/RH holistics recognized significantly more correct inferences than did the supposedly superior REM/LH analytics. The significant four-way interaction suggested that LEM/RH holistics of both sexes made more inferences than their REM/LH analytic cohorts with the exception of females given sentences in logical order. Only in the latter case, and in accordance with the Gurs' theory, the female REM/LH analytics appeared to recognize more inferences than female LEM/RH holistics.

It is of interest that other research measuring subjects' EEG while performing cognitive tasks (Dunn, Singer, & Gould, cited in Dunn, in press) and using visual half-field presentation (Hardyck, Tzeng, & Wang, 1978) has also obtained results contrary to simple hemisphericity theory. Thus, many investigators have suggested that cognitive processing should best be viewed as a complex interaction of the two cerebral hemispheres rather than separate, weighted functions

of each (Ben-Dov & Carmon, 1976; Broadbent, 1974; Dunn, in press, Levy & Trevarthen, 1976).

Another possibility exists, however, that is congruent with simple hemisphericity theory. All of the acquisition and testing items in the present experiments were highly concrete even if they were in sentence form, i.e., The snake crawled in the hat. In his dual coding theory of memory, Paivio (1975) suggests that verbal items, particularly concrete verbal items, are coded into an image or analog system as well as a logical, sequential verbal system. If it is assumed that concrete verbal items have to be coded into images prior to logical processing, then it is possible that LEM/RH holistic college students would have a slight advantage in this task over highly analytic REM/LH subjects not having as much right hemispheric visuospatial processing skill. In other words, LEM/RH college students not only have some analytic skills, as shown by their success in college, but they have a high degree of imaging ability. This may prove particularly useful in inference tasks similar to the ones used in the present experiments. The main weakness of this explanation is that it does not really account for the better performance of LEM/RH holistics on verbal relative to pictorial inferences in Experiment 1. Clearly, further research using abstract as well as concrete acquisition and testing materials is needed to clarify this issue.

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Table 1
Example of Ordering of Stimuli
During Acquisition In Experiments 1 & 2*

Experiment 1		Experiment 2 where L = Logical NL = Non-Logical	
Set A Sentences	1. The snake was on the hat. The hat was in the basket. The basket was in the garden. 2. The frog caught the lizard. The lizard was on the wagon. The wagon was in the tent. 3. The racoon touched the snail. The snail was under the log. The log was in the brook. 4. The boy sprayed the spider. The spider was on the chair. The chair was in the kitchen.	Set A Sentences	1. The snake crawled on the hat. L The hat was in the basket. The basket was in the garden. 2. The wagon was in the tent. NL The frog caught the lizard. The lizard was in the wagon. 3. The raccoon touched the snail. L The snail was under the log. The log was in the brook. 4. The chair was in the kitchen. NL The boy sprayed the spider. The spider was on the chair.
	5. The kitten sat in the box. The box was in the car. The car was in the park. 6. The girl watched the window. The birds were on the window. The window was in the bedroom.		5. The kitten sat in the box. L The box was in the car. The car was in the park. 6. The window was in the bedroom. NL The girl watched the birds. The birds were on the window.
Set B Pictures		Set B Pictures	

*Assuming a subject was given Set A sentences first.

Lateral Eye Movements

7. The squirrell stacked the berries.

The berries were on the book.

The book was under the boat.

8. The ants ate the jelly.

The jelly was on the table.

The table was under the tree.

7. The squirrel stacked the berries.

L The berries were on the book.

The book was under the boat.

8. The table was under the tree.

NL The ants ate the jelly.

The jelly was on the table.

Table 2

Sample Test Items and Testing Sequence
for Hypothetical Subject Given Set A Sentences First

Experiment 1

INFERENCES

Set A (Sentences)

1. The snake was in the wagon.
2. The snake was in the garden (T)
3. The frog was in the tent. (T)
4. The frog was in the brook.
5. The raccoon was in the brook. (T)
6. The raccoon was in the tent.
7. The boy was in the bedroom
8. The boy was in the kitchen. (T)

Set B (Pictures)

9. The kitten was under the tree.
10. The kitten was in the park. (T)
11. The girl was in the bedroom. (T)
12. The girl was in the car.
13. The squirrel was under the boat. (T)
14. The squirrel was in the tent.
15. The ants were under the tree. (T)
16. The ants were in the kitchen.

Experiment 2

INFERENCES

Set A (Sentences)

1. The boy was in the bedroom.
2. The snake was in the garden. (T)
3. The raccoon was in the tent.
4. The snake was in the wagon.
5. The frog was in the tent. (T)
6. The raccoon was in the brook. (T)
7. The boy was in the kitchen. (T)
8. The frog was in the brook.

Set B (Pictures)

9. The squirrel was under the boat. (T)
10. The kitten was in the park. (T)
11. The ants were in the kitchen.
12. The kitten was under the tree.
13. The squirrel was in the tent.
14. The girl was in the car.
15. The ants were under the tree. (T)
16. The girl was in the bedroom. (T)

Table 2 (continued)

Experiment 1

Experiment 2

MEMORY

MEMORY

Set A (Sentences)

Set A (Sentences)

17. The snake was on the book. (T)
18. The snake was in the hat.
19. The hat was in the basket. (T)
20. The hat was in the wagon.
21. The basket was in the tent.
22. The basket was in the garden. (T)
23. The wagon was in the garden.
24. The wagon was in the tent. (T)
25. The lizard was on the wagon. (T)
26. The lizard was under the log.

17. The snake crawled on the book.
18. The wagon was in the tent. (T)
19. The chair was in the kitchen. (T)
20. The log was in the garden.
21. The spider was on the chair. (T)
22. The basket was in the tent.
23. The hat was in the basket. (T)
24. The raccoon touched the lizard.
25. The boy sprayed the spider. (T)
26. The snail was under the boat.

Set B (Pictures)

Set B (Pictures)

41. The kitten sat on the table.
42. The kitten sat in the box. (T)
43. The box was in the car. (T)
44. The box was under the table.
45. The car was under the tree.
46. The car was in the park. (T)
47. The boy watched the birds.
48. The girl watched the birds. (T)
49. The birds were on the window. (T)
50. The birds were on the car.

41. The birds were in the car.
42. The boy watched the birds.
43. The kitten sat in the boy. (T)
44. The car was under the tree.
45. The jelly was in the box.
46. The berries were on the book. (T)
47. The boy ate the jelly.
48. The book was under the boat. (T)
49. The girl watched the birds. (T)
50. The table was in the kitchen.